Cloud Connectivity and Embedded Sensory Systems

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To Henk Sr.

Preface

Computers, great or small, can be found in many digital data producing and processing system nodes. Their performance is steadily increasing, and some have already become miniature supercomputing nodes. More and more of them are connected to the Internet, thereby physically forming very large networks.

The classical networks contain computers that are cabled together. History shows two developments here. On the one hand, we see mainframes becoming personal computers and then notebooks, getting more personal all the time. On the other hand, we see mainframes turning into supercomputers and then server farms into the cloud, getting more into a shared service all the time.

There are many stories about the origin of "cloud computing." The most popular one is that people were diagramming an information-processing architecture on a whiteboard. In order to sketch out the magical process that was finally to do everything, some wrinkles were drawn in the sky and they called it a cloud. This is not a rigid definition and consequently the name "cloud" is used for a lot of things.

A cloud provides shade against the sun. To be in the shade, you have to move regularly. If you do not want that, then take an umbrella. It does not give shade to a lot of people, but it will help you. More or less the same is true for the rain cloud. You can walk around with a pot to water your plants, but it is just a bit of water at a time. Having a cloud makes it much easier.

In the industrial age, we have become accustomed to mass fabrication, mass transport, and mass delivery. Already the Romans had structures to gather and transport water, in order to make it massively available in the city. Otherwise you need to live near the well, and when the well goes dry you have to move. Later the same principle was applied for electricity, again with the main benefit that massive use becomes possible without the need to live next to the generator. In the information age, we want essentially the same, but this time for information and specifically sensor-obtained information.

The Internet has become the aqueduct of modern times, bringing information from the large server farms to each household. At the origin, it is not really a cloud, but let us not be too picky. The point we want to make here is to take the cloud as part of a shared resource in a cyclic bio-like system. This would bring us closer to

the concept of "sensory networks." In talking about such networks, we can easily draw up the network nodes, but to indicate the overall processing function some wrinkles in the sky have to be drawn. Just like a cloud!

The point is that a function can be part of a node, can use some nodes, and can also be handled at a server farm. The function is executed on some resources and we do not want to specify immediately where these resources are located and how much of them are needed. It should be moving dependent on the need, and we do not want to know that and where it moved. In other words, *the network becomes the cloud*!

The nature of the network has also changed, though the backbone is still cabled. However, the introduction of wireless technology has caused the computer to become mobile. And from there, we see other computerized mobile equipment coming into fashion, notable the mobile telephone. Yearly 1.5 billion camera phones are sold!

The rich set of user interactions is currently being augmented with inter-device interactions, making the camera phone a flexible node in a community network. Being based on preferential attachments, its function and construction changes with the whim of the participants rather than on pre-composed orchestration.

But the story does not stop with phones. All kind of products are turning to wireless, if not only to get rid of the cables. The doorbell connects wirelessly to the phone and allows you to answer the doorbell, even when you are not at home. The car seat for the children warns for dehydration of the baby. And in all these new devices, we have computing platforms ranging from simple controllers to graphic accelerators.

Similar networking trends such as in wireless consumer communities are visible in smart energy grids, homeland security systems, and environmental networks. These sensory networks are meant to create awareness in space and time. They may be measuring the presence of an object or a condition, characterizing an object stream or a situational pattern, or even detect abnormalities that are to occur. Different types of sensors can be used for similar purposes, allowing for enhanced system reliability and safety, but they tend to be preferentially attached to the network.

For the network functionality, one can distinguish between cloud, and even swarm and flock computing, the difference being the distribution of the decision control. Just plugging sensors into the cloud is one thing, but the question remains how the extended network itself can be made more intelligent and therefore less dependent on the quality of the individual sensors. We call this *embedded sensory systems*.

Sensory systems are populated by embedded functions that safely combine migrating software on virtualized hardware. It brings the connectivity mechanisms from the global cloud into local clouds of sensor-activated resources. This emphasizes safety for society through ownership of data by a rigorous awareness for the users and their intentions. Such systems will leave a clear mark on society in the coming years.

The Book

It provides conceptually a one-stop entry into the world of intelligent sensory networks, as we envision them to exist in relationship to the computing cloud(s). This is the "ambient intelligence" equivalent of what "cloud computing" means to business intelligence, and therefore the new generation of large-scale sensory networking systems. Cloud computing usually refers to the accessibility from the network of a well-orchestrated data warehouse. Clearly, cloud computing concepts also apply to networks of embedded sensors. The book discusses concepts, problems, and initial solutions for the latter, while also providing illustrations from a wide field of practice. Becoming aware of the basic problems and solutions helps the readers to prepare for innovation based on distributed intelligence in their own area of technological expertise.

This book provides new theory on the design of wireless sensory networks. It provides a step-by-step discourse on building case studies to capture the requirements, taking into account practical limitations to creating ambient intelligence. Notably, it pays attention to topological and communication constraints, while adding intelligence, security, and safety to the overall desired system functionality. Such aspects will be highlighted by reviewing applications in a variety of typical sensory/cloud network scenarios.

The reader will not only achieve a better understanding of such concepts as sensory clouds but will also be guided by examples on how to design such networks, taking the typical characteristics of diverse application areas into account.

In general, knowledge on new technologies is communicated in new conferences and journals, and in addition needs to be condensed regularly in books. This book will give the readers an overview of the current directions in theory and practice and will therefore allow them to stand on the shoulder of "giants"/peers. Our emphasis in writing this book has been on developing the new concepts, especially the disruptive technology aspects, for use in the establishment of new businesses.

The book is divided into four parts. The first part explores the opportunities that will come about from the further developments of cloud computing into the outlying domains of sensory systems. It also includes a description of a new software model for large-scale networks. The second part reviews system design aspects needed for the understanding of the subsequently illustrated potential sensory network applications. The emphasis is on system applications that would benefit from the connection into the Cloud. The third part addresses concerns for security and safety that will need to be supported in order to result in successful cloud-centric sensory networks. Lastly, we focus on details of a futuristic sensory/display-instrumented home environment completely in touch with the Cloud.

This book aims to be one of the first to bring the sensor-networking-into-the-cloud state-of-the-art together with a perspective on the near future to stimulate further research. It provides a selection of material from courses at Lund University (Sweden) and the Daniel Webster College in Nashua (New Hampshire, USA). It brings a vision that has gradually evolved from the experience with

a number of students. Especially our gratitude goes to Wen Hai Fang, Peter Sundström, Lars Lundqvist, Erik Ljung, Erik Simmons, Barbara Olmedo, Sajjad Haider, Joe Evans, Dalong Zhang, Miao Chen, Mona Akbarniai Tehrani, Shankar Gautam, Olle Jakobsson, Lijing Zhang, Wang Chao, Shkelqim Lahi, Nabil Abbas Hasoun, Dongdong Chen, Bintian Zhou, Cheng Wang, Deepak Gayanana, Markus Ringhofer, Vince Mohanna, Johan Ranefors, Suleyman Malki, Jos Nijhuis, and Ravi Narayanan.

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Contents

List of Figures

List of Tables